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# EMBRYO AND SEED DEVELOPMENT IN THE NYCTAGINACEAE
# I. STUDIES IN THE GENUS *BOERHAAVIA*

BY

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*Communicated by A. C. Joshi*

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## Introduction

The present paper deals with the various stages in the development of the embryo and seed of *Boerhaavia diffusa* Linn. and *Boerhaavia repanda* Willd., two members of the family Nyctaginaceae found in the Gangetic plain and other parts of India. The development of the embryo-sac and the pollen in these plants has already been described by Maheshwari (1929) and Bhargava (1932). They have also made a few observations on the embryo development, but these are of a fragmentary nature, and do not provide a correct picture of the same as pointed out by me in a preliminary note (Kajale, 1936).

Out of the two plants described here, *Boerhaavia diffusa* has been studied in greater detail than the other. Both the plants, however, resemble each other very closely. A common account, therefore, has been written, the few differences in details being pointed out at the proper places.

## The Ovule

The carpel in these two species of *Boerhaavia*, as in the Nyctaginaceae in general, possesses a single basal ovule. This is provided with a short funicle. The form of the ovule has been described by Maheshwari (1929) as anatropous. The material examined by me, however, shows that there is a distinct bend in the ovule on the side of raphe, pointing towards campylotropy. The figures of Maheshwari and Bhargava also show this clearly. The ovule thus has the same form as in *Gisekia pharnaceoides* studied by Joshi and Rao (1936), and should be described in the same way as ana-campylotropous.

Another point missed by Maheshwari (1929) and Bhargava (1932) is about the development of the epidermal cap at the micropylar end of the nucellus. Figures 29 and 32 of Maheshwari and 39 and 41 of Bhargava show clearly the development of such cap,

but the authors have not referred to this point in the text. The presence of the nucellar epidermal cap in these forms tends to bring the Nyctaginaceae into line with the other Centrospermales, for the development of such a cap seems to be a characteristic feature of this order.

In *Boerhaavia repanda,* Bhargava (1932) has described the formation of a mucilaginous mass near the micropyle of the ovule. Such a structure is seen in *Boerhaavia diffusa* also. It is, however, nothing more than the continuation of the transmitting tissue of the carpel. Similar tissue is also seen in *Mirabilis Jalapa* and Guéguen (1901) had long ago worked out its true nature.

## The Development of the Embryo

The first division in the fertilised egg is by a transverse wall and leads to the differentiation of an apical and a basal cell (Fig. 3). The next division takes place in the basal cell (Fig. 4), and as again transverse. In this manner a filamentous proembryo of three cells is formed (Figs. 5, 9 & 20). The proembryo may remain in this condition till the appearance of the first longitudinal wall or another transverse division may take place in the cell at the micropylar end, and the proembryo may become four cells long before the apical cell divides longitudinally (Fig. 6). Further increase in the length of the embryo takes place always after the appearance of a longitudinal wall in the apical cell, and again is the result of a transverse divison in the micropylar cell. Thus every increase in the length of the embryo up to this stage is due to repeated divisions in the micropylar cell. This is clearly brought out by figure 1.

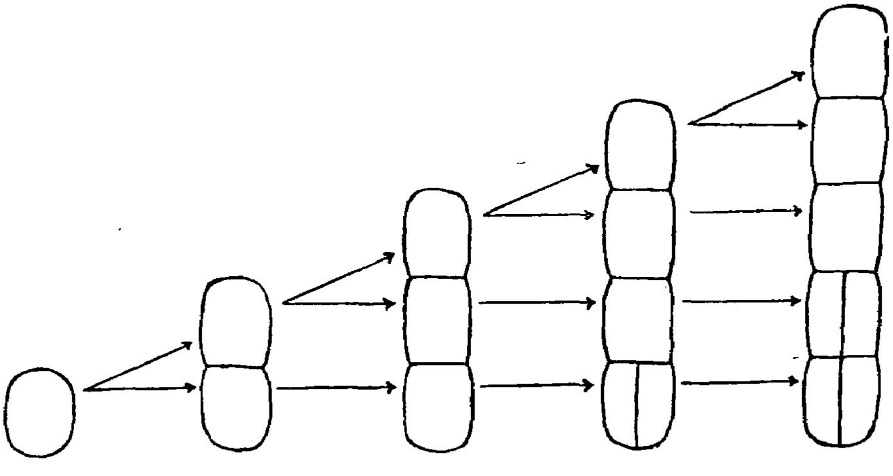


Fig. 1. A diagramatic sketch of the development of embryo till it has become 5 cells long, showing the derivation of various cells by repeated divisions in the basal cell.

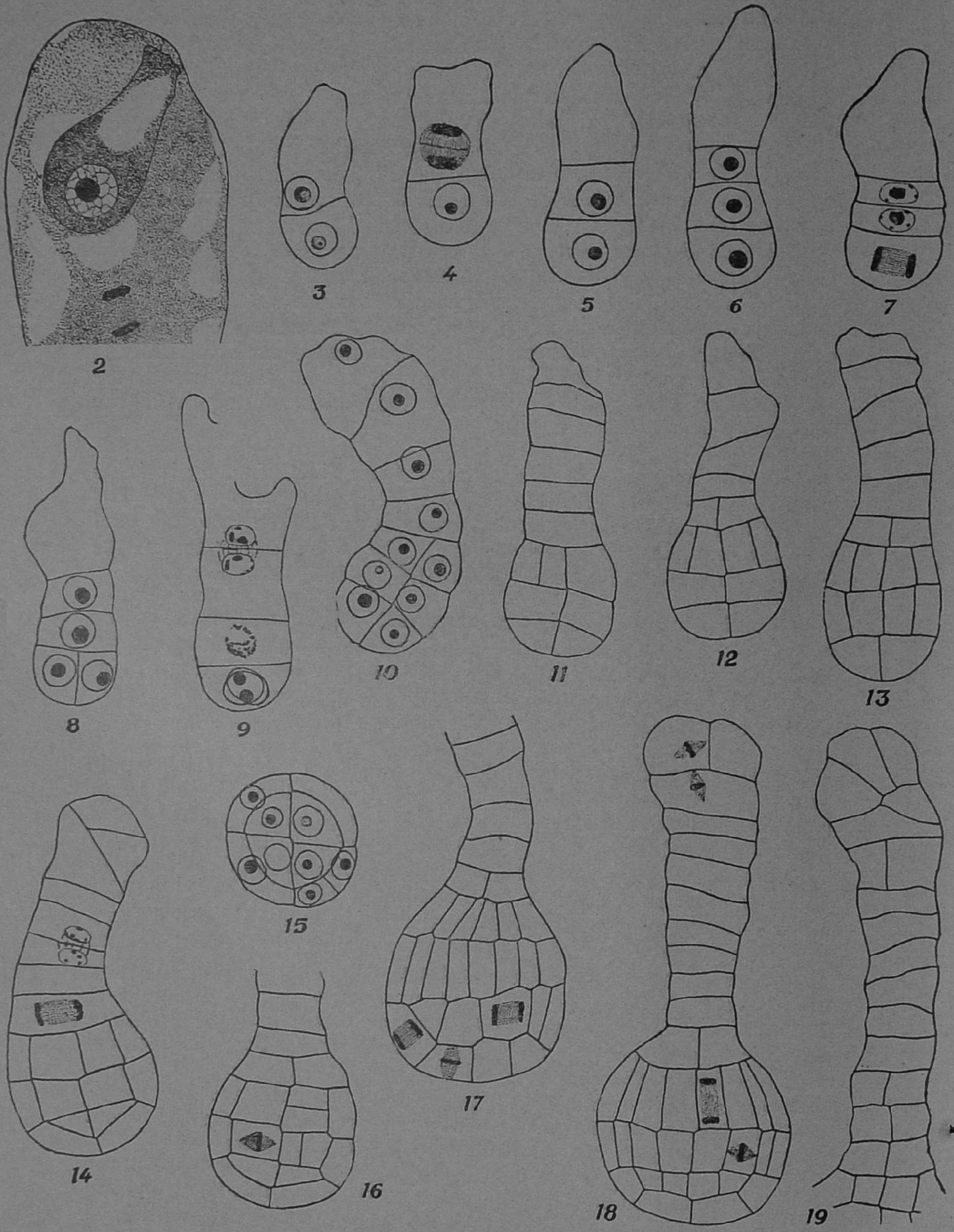
The embryo proper develops from four apical cells of the proembryo, but the time of differentiation of these four cells is peculiar as compared with the members of the Amarantaceae (Joshi and Kajale, 1937), Chenopodiaceae (Souèges, 1920), Caryophyllaceae (Souèges, 1924), etc. In the latter families these cells are all formed and can be counted before any longitudinal division begins in the cells of the proembryo. In the plants under investigation one or two of the lower cells, depending upon the total number of cells of the proembryo, are not even formed when the first longitudinal division takes place in the apical cell. These cells are cut off only afterwards from the micropylar cell. Figures 7, 8 and 9 from *Boerhaavia diffusa* and figure 21 from *Boerhaavia repanda* show this point clearly. In figure 9 for instance the apical cell has divided longitudinally into two. The penultimate one is dividing in the same manner. The third cell which has to take part in the development of the embryo proper is just differentiating, while the fourth one is still to be cut off.

The differentiation of the embryo from these four cells is as follows: the apical cell forms the cotyledons and the plumule. The second and third cell from the apex give rise to the hypocotyl and the greater part of the radicle. The fourth cell forms the hypophysis, from which the apex of the radicle is completed.

Generally four cells only are concerned in the development of the embryo. A few cases in *Boerhaavia repanda,* however, have shown that some times five cells may take part in its development. Figures 27 and 28 provide two such illustrations. The accessory cell takes part in the development of the hypocotyl and radicle.

As the embryo reaches a length of three or four cells, longitudinal walls begin to appear. The first longitudinal division takes place in the apical cell (Figs. 7, 8 & 21). It is this feature which has probably led Maheshwari (1929) to conclude that the embryo development in *Boerhaavia diffusa* corresponds to the *Capsella*-type. Next such a wall appears in the penultimate cell (Figs. 9, 21 & 22), and this is followed by a longitudinal division in the third cell from the apex (Figs. 10 & 23). This sequence of the appearance of longitudinal walls is in direct contrast with what is seen in other investigated members of the Centrospermales, e.g., *Chenopodium Bonus-Henricus* (Souèges, 1920), *Alternanthera sessilis* and *Digera arvensis* (Joshi and Kajale, 1937), *Achyranthes aspera* (Kajale, 1937), *Gisekia pharnaceoides* (Joshi and Rao, 1936), and *Sagina procumbens* (Souèges, 1924). In all these examples the first longitudinal division takes place either in the second or third cell from the apex, and then only it proceeds towards the apical cell.

As the longitudinal division takes place in the third cell or soon after its completion, the apical cell undergoes one more longitudinal division in a plane at right angles to the first, and thus gives rise to




Figs. 2-19. *Boerhaavia diffusa.* Fig. 2, micropylar part of an embryo-sac showing the fertilised egg and the dividing endosperm nucleus. Figs. 3-18, various stages in the development of the embryo. Fig. 15 represents a transverse section of one of the three apical cells and shows the formation of quadrants. In Figs. 16 & 17 micropylar part of the suspensor is not shown. Fig. 19 shows the structure of the suspensor. For further explanation see text. × 450.

the quadrants (Figs. 15 & 23). This is followed by the organisation of quadrants in the second and third cells.

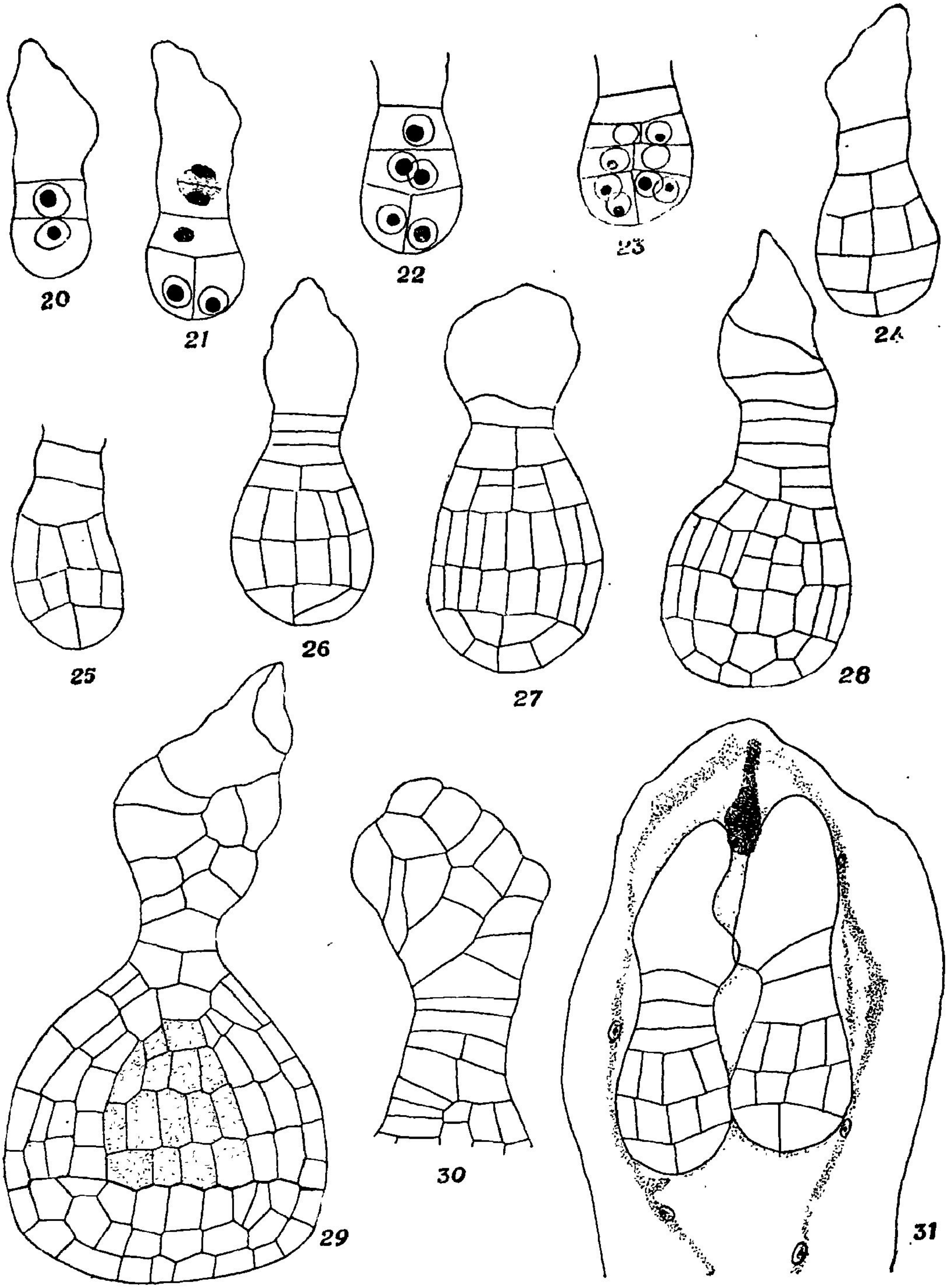
After the quadrants have been organised in the three tiers each cell divides by a periclinal wall. Thus the dermatogen differentiates. It first appears in the third tier from the apex, next in the second, and finally in the apical tier (Figs. 11 to 14 & 24 to 26).

After the dermatogen has been completed, the differentiation of the two other histogenic layers begins. This proceeds in a very interesting way and differs markedly from what is seen in other angiosperms. Generally in the flowering plants the dermatogen cells after their differentiation divide only by anticlinal walls, so that this layer may keep pace with the growing embryonal mass. In species of *Boerhaavia,* however, these cells also divide once periclinally (Figs. 17, 18, 27 & 28). The resultant inner cells give rise by further periclinal divisions to the periblem of the embryo. The cells cut off towards the outside do not divide any further periclinally, and appear to behave from now onwards like the dermatogen of other angiosperms. The inner cells cut off by the first periclinal divisions in the quadrants differentiate into the plerome of the embryo (Fig. 18). The rest of the development of the embryo, including the development of the hypophysis, is quite similar to that of *Chenopodium Bonus-Henricus* as described by Souèges (1920).

The suspensor develops from the micropylar cell formed after the hypophysis cell has been cut off, i.e., from the sister cell of the hypophysis. Its structure differs in the two species of *Boerhaavia.* In *Boerhaavia diffusa,* it is a long and slender structure. Ten to thirteen cells can be counted in its length, but through its greater part it is only one or two cells broad (Figs. 18 & 19). The suspensor of *Boerhaavia repanda* differs from that of *Boerhaavia diffusa* in being shorter in length but more massive (Figs. 29 & 30). It thus seems to agree with that of *Mirabilis Jalapa* described by Woodcock (1929). I can not bear out the statement of Bhargava (1932) that in *Boerhaavia repanda* "sometimes the suspensor has two rows of cells at places and occasionally even in older stages remains uniseriate."

## Mature Embryo

The mature embryo is not exactly annular as in many other Centrospermales but is bent over the columnar perisperm (Fig. 32). The bend exists in the region of the hypocotyl. The radicle and the cotyledons consequently are straight and nearly parallel in longitudinal section. The cotyledons in transverse section appear more or less concave (Fig. 33), and the inner one is seen to be smaller than the outer. They are further characterised in *Boerhaavia repanda* by the presence of certain cells, which are bigger than the rest and contain raphides of calcium oxalate. These raphides are absent from the hypocotyl and the radicle, and are not found at all in any




Figs. 20-31. *Boerhaavia repanda*. Figs. 20-29, various stages in the development of the embryo. The dotted part in fig. 29 represents plerome. Fig. 30 shows the structure of the suspensor. Fig. 31 represents micropylar part of an embryo-sac showing two embryos equally developed. A degenerating pollen-tube is seen at the top in between the two embryos. For further explanation see text. × 450.

part of the embryo of *Boerhaavia diffusa.* Procambial tissue, similar to that described by Woodcock (1929) in *Mirabilis Jalapa,* is developed in the embryo of both the species of *Boerhaavia.*

Starch is deposited more or less uniformly in the different parts of the embryo, except in the apical part of the radicle. It is less abundant in this region, and at the extreme apex is not found at all. The starch grains in the procambial tissue are smaller in size and less abundant than in other layers. The deposition of these grains takes place rather late in the development of the embryo.

## Polyembryony

An example of polyembryony has been observed in *Boerhaavia repanda.* This is shown in Fig. 31. The accessory embryo is seen to develop from a synergid.

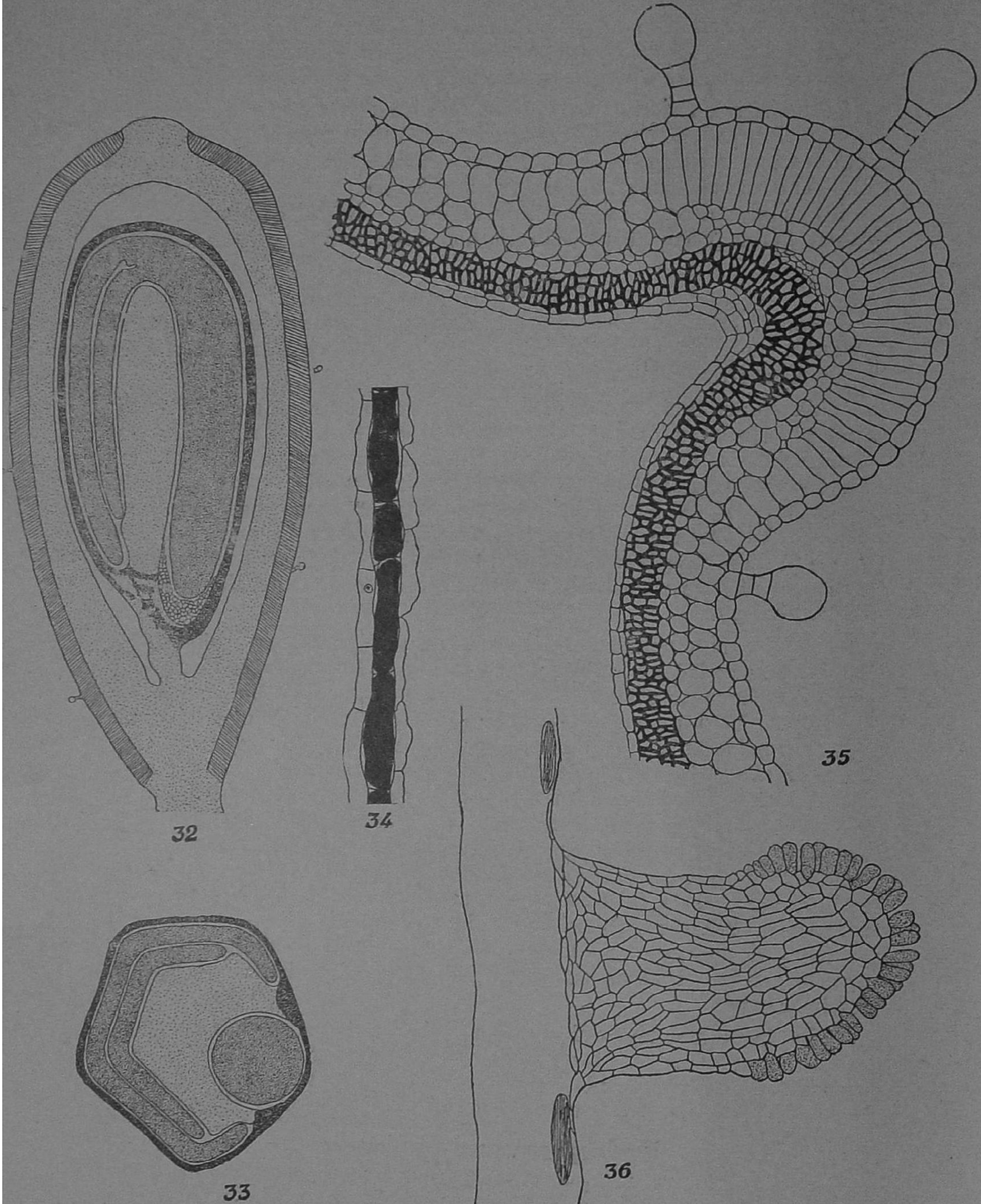
There are two conditions, which seem to be responsible for this kind of development, the occurrence of egg-like synergids and the penetration of accessory pollen-tubes into an embryo-sac. During the course of investigations going on in this department on the embryology of the flowering plants, both these conditions have been noted quite frequently in several families of the Centrospermales. It could, therefore, be anticipated that in some cases the simultaneous presence of these characters would lead to the development of polyembryony.

In the Nyctaginaceae, the presence of accessory pollen-tubes has been recorded by Maheshwari (1929) in *Boerhaavia diffusa,* and the writer has also observed the presence of such tubes in *Boerhaavia repanda.* Two pollen-tubes were also seen penetrating the ovule showing polyembryony. The presence of egg-like synergids has been seen by the writer in *Boerhaavia diffusa.* In *Boerhaavia repanda,* the material of pre-fertilisation stages has not been examined, but as the two species are very similar in all their embryological features, egg-like synergids are likely to occur in this species as well. The vacuolation of the basal cells of both the embryos from the polyembryonous ovule is seen to be egg-like. It can, therefore, be concluded that the polyembryony in *Boerhaavia repanda* has most probably developed from the fertilisation of an egg-like synergid by a male gamete from an accessory pollen-tube in addition to normal fertilisation.

In the family Nyctaginaceae, no other instance of polyembryony has been recorded so far. Johri (1936) has reported recently a parallel case of polyembryony in *Sagittaria graminea,* and more examples of a similar nature are cited by Dahlgren (1927).

## Endosperm and Perisperm

The primary endosperm nucleus divides before the egg (Fig. 2). By its repeated division it forms a large number of nuclei, which are scattered in the protoplasmic lining of the embryo-sac. The endosperm becomes cellular in the micropylar region forming a cap




Figs. 32-36. *Boerhaavia diffusa*. Fig. 32, a longitudinal section of the fruit along with the perianth. It shows a well-developed embryo, endosperm and perisperm. Fig. 33, transverse section of the fruit showing two cotyledons, radicle and perisperm. Fig. 34, a part of the transverse section of the testa and pericarp fused together. Fig. 35, a part of the transverse section of the perianth. Fig. 36, a longitudinal section of a gland from the perianth of *Boerhaavia repanda*. Areas marked with lines represent cells containing raphides. Fig. 32 has been reconstructed from a number of adjacent sections. Figs. 32-33, × 25; Fig. 34, × 900; Fig.35, × 120; Fig. 36, × 100.

of cells over the apex of the radicle (Fig. 32). The larger part of it is absorbed in the free nuclear condition by the developing embryo, as described by Woodcock (1929) in *Mirabilis Jalapa.* The endosperm development in the Nyctaginaceae thus corresponds to the *Melandrium*-type of Rócen (1927).

The central part of the nucellus is left in the mature seed as perisperm in between the cotyledons and the radicle (Figs. 32 & 33). Starch grains are abundantly deposited in this region and serve as the reserve food for the embryo.

## Pericarp and Testa

The ovary wall is many cells thick to begin with, but during the development of the embryo the inner layers are crushed and only the outermost layer persists in the mature fruit. This represents the pericarp. It consists of empty cells and fuses with the testa of the mature seed as in the caryopsis of the grasses.

The testa in the fully developed seeds consists of three to four layers of cells in *Boerhaavia repanda* and two to three layers of cells in *Boerhaavia diffusa.* In the former plant the cells of the testa are empty and there is no deposition of any grains in their cells. The testa in *Boerhaavia diffusa* consists of two parts (Fig. 34). The inner part is of one or two layers of empty cells. The outer part consists of a single layer of cells, in which some grains probably of the nature of aleurone grains are deposited. These grains in the beginning are separate from each other, but ultimately they unite together and form a mass of brownish yellow substance, which occupies whole of the cell (Fig. 34). The deposition of the grains extends to the inner layers along the margins of the outer cotyledon. Some similar grains are also deposited in the region of the funicle (Fig. 32).

## Structure of the Perianth

As in the Nyctaginaceae in general, the lower part of the perianth persists as an envelope for the fruit (Fig. 32). The structure of it differs in the two species of *Boerhaavia.* In *Boerhaavia diffusa,* it has five ribs and an equal number of furrows alternating with the ribs. On both sides it is covered by epidermal layers (Fig. 35). The outer epidermis bears numerous glandular hairs both in the region of the ribs and furrows (Fig. 35). Each gland has a stalk of three to five cells and a one-celled head, as described by Maheshwari (1929). Below the external epidermis under the ribs there is a layer of palisade-like sclerenchymatous cells, followed by a few layers of parenchyma cells. In the region of the furrows corresponding to these tissues is found the spongy mesophyll. Next in both the regions of ribs and furrows there is seen a continuous band of fibrous sclerenchymatous cells, followed by one or two layers of parenchymatous cells and the inner epidermis. There are five

main vascular bundles, one below each rib, as described by Joshi and Rao (1934). Aleurone grains similar to those in the testa are deposited in the outer and inner epidermis and one or two layers of parenchyma on either side of the sclerenchymatous fibres. Similar grains are also commonly observed in the glandular hairs.

The perianth of *Boerhaavia repanda* has ten ribs and as many furrows. The outer surface of it is covered by large glands, which are developed on the ribs only. The structure of one such gland is sketched in figure 36. It consists of a large multicellular stalk carrying numerous glandular cells at its apex. The latter (dotted in the figure) take darker stain than the rest. They are radially elongated and have a nucleus at the base.

The wall of the perianth in *Boerhaavia repanda* consists mostly of parenchyma cells, in which ten columns of sclerenchymatous cells are developed below the ten ridges. There are ten vascular bundles, one below each rib, as noted by Joshi and Rao (1934). As in *Boerhaavia diffusa* aleurone grains are deposited in some cells of the perianth.

Raphides of calcium oxalate are abundantly deposited in both the species of *Boerhaavia* in the perianth.

## Discussion

Comparison of the embryo development in the Nyctaginaceae with that of other families of Centrospermales like Caryophyllaceae, Amarantaceae, Chenopodiaceae and Molluginaceae shows that it resembles the latter families in the fact that four or occasionally five cells take part in the development of the embryo. It, however, differs in four important points. In the Nyctaginaceae after the first division of the fertilised egg, subsequent transverse divisions, up to a certain stage at least, take place in the basal cell only. This feature is in direct contrast with what is seen in the Caryophyllaceae, where the basal cell never divides and the rest of the proembryo develops only from divisions in the apical cell of the two-celled proembryo. The Chenopodiaceae occupies an intermediate position. Here both the cells, resulting from the first transverse division of the fertilised egg take part in the development of the proembryo.

The four apical cells, that form the embryo in the Nyctaginaceae, differentiate gradually unlike other Centrospermales. By the time the apical cell has divided longitudinally one or two cells out of these four are not even formed. They are cut off later by the basal cell. In other families of the Centrospermales the cells that form the embryo are all differentiated before any longitudinal division takes place in the proembryo.

The sequence, in which the longitudinal divisions appear in the proembryo in the Nyctaginaceae is quite different from what is seen in the Caryophyllaceae, Chenopodiaceae, Amarantaceae and

Molluginaceae. In the latter families the first longitudinal division takes place in the second, third or fourth cell from the apex, and then extends towards the apical cell. In the Nyctaginaceae the first longitudinal division is seen in the apical cell, next in the penultimate cell and finally in the third cell.

The development of the three histogenic layers in the Nyctaginaceae is very peculiar. The periblem originates from the dermatogen and is not a sister layer of the plerome as in other flowering plants.

## Summary

The paper deals with the embryo and seed development in *Boerhaavia diffusa* and *Boerhaavia repanda*.

The first division of the egg is by a transverse wall to form a basal and apical cell. The former then divides repeatedly to make the embryo five cells long. Simultaneously with these transverse divisions progressing in the basal cell longitudinal walls begin to appear in the proembryo. The first appears in the apical cell, next in the penultimate cell and finally in the third cell from the apex. These three cells along with a fourth cell adjacent to the third give rise to the embryo proper. The apical cell gives rise to the plumule and the cotyledons. The second and third form the hypocotyl and the greater part of the radicle, while the fourth cell is the hypophysis and completes the root apex.

The differentiation of the three histogenic layers is very peculiar. The periblem is cut off from the dermatogen and is not a sister layer of the plerome as in other angiosperms.

The suspensor develops from the micropylar cell of the proembryo, after it has cut off the hypophysis cell. It is long and slender in *Boerhaavia diffusa* and short and massive in *Boerhaavia repanda*.

A case of polyembryony resulting from the development of an extra embryo from a synergid has been observed in *Boerhaavia repanda*.

The endosperm becomes cellular only in the micropylar region of the embryo-sac.

The testa and pericarp fuse together in the mature seed.

Other features of the seed are of the usual Centrospermalean type. The structure of the perianth is described in the body of the paper.

My sincere thanks are due to Dr. A. C. Joshi for his kind interest and helpful suggestions during the progress of the investigation.

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# THE GROWTH OF RICE SEEDLINGS IN SALT SOLUTIONS OF DIFFERENT H-ION CONCENTRATIONS

BY

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*Received for publication on 9th March, 1938*

In the recent work on the intake of nitrogen by the rice plant Dastur and Malkani (1933) carried out different types of water culture experiments and they have shown by chemical analysis of the culture solutions that the ammoniacal nitrogen absorption by plants is high in the early stages and low in the latter stages of growth while the absorption of the nitrate nitrogen follows the reverse order. They have also shown by using different ammonium salts that the order for the absorption of ammonia from the respective salts was sulphate, phosphate, nitrate and chloride in the early stages of growth, while in the case of nitrate salts the order of absorption of nitrate ions from the respective salts were in the order ammonium, potassium, magnesium, calcium and sodium. Greatest absorption of ammoniacal and nitrate nitrogen occurred from ammonium sulphate and ammonium nitrate respectively.

Though the absorption of nitrogen from different ammonium salts and nitrate may depend on the kind of the salt used, it does not follow necessarily that the growth of plants kept in these salts was affected in the same order as the absorption of nitrogen from these solutions. These authors have not measured side by side the growth of the rice seedlings kept in the different solutions of ammonium and nitrate salts. Whether greater absorption of ammonium or nitrate ions from these salts, viz., ammonium sulphate and potassium nitrate, is accompanied by greater growth of the Rice seedlings kept in these solutions is not determined. If this is so, the growth made by the seedlings would be less and less in the salts of ammonia in the order sulphate, phosphate, nitrate and chloride. Similarly the growth made by the seedlings in the solutions of different nitrates would be less and less in the order ammonium, magnesium, calcium and potassium nitrates during the early stages of rice seedlings.

It was, therefore, undertaken to measure the growth of the seedlings kept for a definite period in salts containing ammonia and nitrate. It was found useful not to restrict the scope of experiments to single salt solutions but also to use different combinations of these salts. The object of this investigation is to find out the solution in which the growth of the rice seedlings is at its maximum.

In order to carry on this investigation, different factors affecting the growth of seedlings in culture solutions must be taken into account so as to obtain true relationship between the growth of the seedlings and the salt solutions used. Firstly, the importance of the acidity and alkalinity of the medium on the growth of plants is very well known, and important data on the relation between plant and the alkalinity and acidity of the external media are already collected on different plants by various workers—*i.e.* Hoagland (1918), Duggar (1920), McCall and Haag (1921) and many others.

Jacobson (1925) grew rice plants in four different nutrient solutions and found that the pH value decreased from 5·0 to about 3·5 during the first 24 hours and it remained practically constant for 3 days. It may be due to the absorption of the basic ions in a greater proportion than that of the acidic ions of the salts or it may as well be due to the excretion of carbon dioxide by the plant-roots. In India, Mitra and Phukan (1929) determined the effect of different pH values of nutrient solutions on the growth of the roots of rice seedlings one month old. They used the length of the roots as a measure of growth and found that the highest root development was obtained at a concentration of 0·03% of NaOH, *i.e.*, at pH 7·9 and that pH 3·9 was distinctly toxic.

From the review of the previous work given in the above para, it appears that two important points must be taken into consideration in the arrangement of the experiments. The pH of each salt solution must be so controlled by the addition of weak alkali or weak acid as to obtain a wide range of pH values with a graduation of 0·2; secondly the pH of the solution should be kept constant by the addition of weak acid or alkali as the case may be every twenty-four hours during the period of experimentation. This is necessary as the plants affect the reaction of their external media. Amongst those who have worked on the subject Veitch (1902), Breazeale and Le Clerk (1912), Jones and Shive (1922), Hoagland (1918), Conner and Sears (1922), and Olsen (1923) may be mentioned. Some workers found that the direction of the pH changed towards neutrality if the original pH was towards the acidic side while others found that the direction of the change depended on the plant used. Arrhenius (1922) has studied the effect of the rice plant on the pH of the nutrient solutions. In all cases the rice plant brought the pH of all nutrient solutions with different initial values to 6·2.

The second important factor to be taken into consideration is the total osmotic values of the nutrient solutions used. The osmotic

values of the nutrient solutions used should be approximately the same, otherwise the comparison of growth made by the rice plants in different solutions may not be strictly valid. For this reason iso-osmotic solutions of different salts should be used. The salt solutions should be periodically renewed, preferably twice a week, otherwise the concentration-changes brought about in the solutions may effect adversely the growth of rice seedlings.

## Methods Adopted

The H-ion concentration of the cultures and various salt solutions used were determined by the colorimetric method given by Clark (1920). The results of pH obtained by this method were also verified by the quinhydrone electrode method in some cases.

In order to obtain the desired pH value of a salt solution, weak alkali or weak acid as required was used. The acid used was 0·2 Normal phosphoric acid and for the alkali N/40 sodium bicarbonate was used.

Rice seeds of the Columba variety 42 were soaked in water for 24 hours and allowed to germinate in saw dust. Watering was done twice a day, once in the morning and once in the evening. When they were 14 days old they were taken out of the saw dust and washed thoroughly first with tap water and then with distilled water. Healthy seedlings with equally developed roots were selected from this lot. The length of the roots taken was generally 4 inches. 480 such seedlings were selected for each series.

Cylindrical jars of about 1,500 c.c. capacity are chosen, and in each jar 30 seedlings are kept to grow. The jars are fitted with wooden covers bearing six holes, each hole carrying 5 seedlings. The inside of the jars was completely paraffined so as to prevent any change in the pH value of the solutions due to the solubility of glass in water.

The culture solution used was that given by Knops as modified by Tottingham.

It was first undertaken to determine the effect of the omission of iron from the normal culture solution on the growth made by the rice seedlings as there is a great deal of difference of opinion on the availability of iron to the rice plant. It has been maintained by Gile and Carrero (1920) and Willis and Carrero (1923) that nitrates are less valuable as a source of nitrogen than ammonium salts since the former cause unfavourable soil reaction and unavailability of iron, though this view has been disputed by Metzger and Janssen (1928).

It was, therefore, first undertaken to study the effect on the growth of Rice seedlings of (*i*) omission of iron, (*ii*) addition of ferrous sulphate and ferric phosphate separately and (*iii*) replacing

potassium nitrate by ammonium sulphate in the culture solutions. The pH of each of these solutions was kept varied from 3·6 to 7·0 with a graduation of 0·2 pH except in the first case where the graduation is 0·6 pH.

Four series of experiments containing (*i*) culture with $FeSO_4$, (*ii*) culture with $FePO_4$, (*iii*) culture without Fe and (*iv*) culture with $(NH_4)_2SO_4$ instead of $KNO_3$ were started. The experiments were carried in triplicate. The 14 days old seedlings germinated in saw dust were kept in the culture jars and they were allowed to grow for a fortnight in all cases. The results are given in Table I, and Figure 1.

## TABLE I

**Weights of roots and leaves in mgs. of Rice Seedlings**

**Average of 3 sets of experiments**

| pH | Culture with $FePO_4$ | Culture with $FeSO_4$ | Culture without Fe | Culture with $(NH_4)_2SO_4$ in place of $KNO_3$ |
|---|---|---|---|---|
| 3·6 | 233·3 | 233 6 | 233·2 | 233·4 |
| 4·2 | 238·2 | 234·0 | 233·1 | 233 6 |
| 4·4 | 239·6 | 235·0 | 233·7 | 234·7 |
| 4 6 | 239·6 | 236·0 | 234 8 | 235·3 |
| 4 8 | 240·0 | 236 1 | 235·0 | 235·0 |
| 5·0 | 241·7 | 235·6 | 235·2 | 236·8 |
| 5·2 | 242·5 | 236·7 | 236·3 | 238·0 |
| 5 4 | 246·3 | 238·0 | 237·0 | 237·4 |
| 5·6 | 247·4 | 239·0 | 238 0 | 239·4 |
| 5·8 | 248·6 | 240·0 | 239·0 | 241·4 |
| 6·0 | 249·4 | 243·6 | 240 0 | 242·0 |
| 6·2 | 250·2 | 244·3 | 244 0 | 242·8 |
| 6·4 | 251 8 | 245·0 | 245·0 | 244 0 |
| 6 6 | 252·5 | 245 7 | 247·0 | 244·6 |
| 6·8 | 260·0 | 246·5 | 249·0 | 245·6 |
| 7·0 | 261·3 | 246·0 | 250·0 | 245·5 |

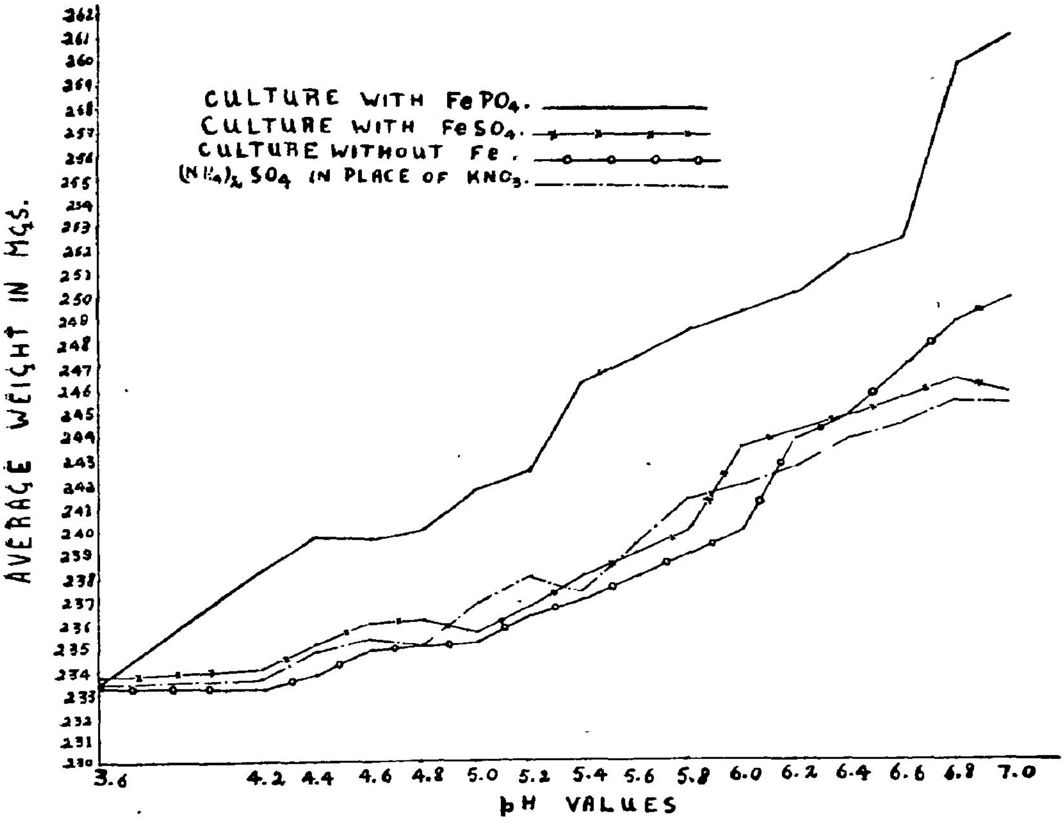


FIG. 1

Average weights of rice seedlings grown in different culture solutions.

In order to determine the solution in which the highest growth of the seedlings takes place, it was necessary to analyse statistically the data by Fisher's method of Analysis of Variance. The total variance is to be divided into that due to different pH, that due to different treatments and the residual variance, which in the present case is the variance due to the interaction of pH and treatments. Results of differences between the mean yields are given in Table II.

## TABLE II

**Differences between the mean yields**

| | Culture with $FePO_4$ | Culture without $FePO_4$ | Culture with $FeSO_4$ | Culture with $(NH_4)^2SO^4$ |
|---|---|---|---|---|
| Culture with $FePO_4$ | — | —59·4 | —60·2 | —63·0 |
| Culture without $FePO_4$ | +59·4 | — | — 0·8 | —3 |
| Culture with $FeSO_4$ | +60·2 | 0·8 | — | — ·8 |
| Culture with $(NH_4)_2SO_4$ | +63·0 | 3·6 | 2·8 | — |

Double lines indicate significance at 1% level.

The culture with $FePO_4$ is highly superior to all the other three treatments, the differences between which are statistically non-significant. The above conclusion is evident from the examination of Table I and the graphs given in Fig. 1. It can also be seen that the pH of each culture solution has great effect on the growth of the rice seedlings irrespective of the salts used. The rice seedlings show very little growth in very acidic solutions. The dry weights of the seedlings are very low in the solutions of pH 3·6—5·0. The growth is the highest in solutions of very low acidity with pH between 6·6 and 7·0.

Replacement of potassium nitrate by ammonium sulphate in the culture solution shows no beneficial effect on the growth of the seedlings.

In the second year of this investigation it was undertaken to study the effect of nitrates and ammonium salts on the growth of the rice seedlings. In these experiments the procedure adopted differed in two important aspects. In the first case the pH of each culture solution was maintained the same by the addition of phosphoric acid or sodium bicarbonate as the case may be every 24 hours. The procedure of bringing the pH of a solution to its initial value every 24 hours is described above in the methods. The second important departure was the renewal of culture solutions every week. This was necessary in order to maintain the original ionic concentrations of the salts used. Period of one week is selected on account of the findings of Dastur and Malkani (1933) that an equilibrium between the internal concentration and external concentration of an ion like the ammonium ion is reached when the rice plants are kept for a week in a solution of salts.

In the first place three nitrate salts and three ammonium salts were taken and the solution of these salts were individually used for determining the effect on the growth of the rice seedlings. The range of pH values used in each case was the same as before and the experiments were made in triplicate series. The salts used were nitrates of potassium, magnesium and sodium and the ammonium salts used were sulphate, phosphate and chloride.

The results obtained are very interesting. The growth of the rice seedlings is greater in the solutions of high pH than in the solution with low pH in the case of all the salts. In the case of potassium the dry weight of the seedlings increases in solutions of pH above 5·0; it means that higher acidity in potassium nitrate solutions retard growth. The same is true of the dry weights of the rice seedlings in the ammonium sulphate solutions. In the case of ammonium phosphate solution marked increase in dry weight occurs in solutions of pH values lower than in the preceding two cases, and beyond pH 6·6 the dry weights of the seedlings show a definite decline. Very little growth is made in ammonium chloride

solutions while it is medium in solutions of nitrates of magnesium and sodium. Thus the most favourable pH in the acidic range is near 7·0 except in the case of ammonium phosphate where the most favourable range of pH for growth lies between 6·2 to 6·6. It appears that in the solutions of different salts with a low pH value, the latter becomes a limiting factor in the growth of the seedlings irrespective of the nature of the salt used. The differential effects on growth of the seedlings of different salts become visible as the pH values of the solutions rise from about 5·0 onwards. Then the different salts used stand in the order $(NH_4)_2SO_4=(NH_4)_3PO_4 > KNO_3 > Mg(No_3)_2 > NH_4Cl = Na\,NO_3$ so far the growth of the seedlings can be judged from the results in Table III and Fig. 2.

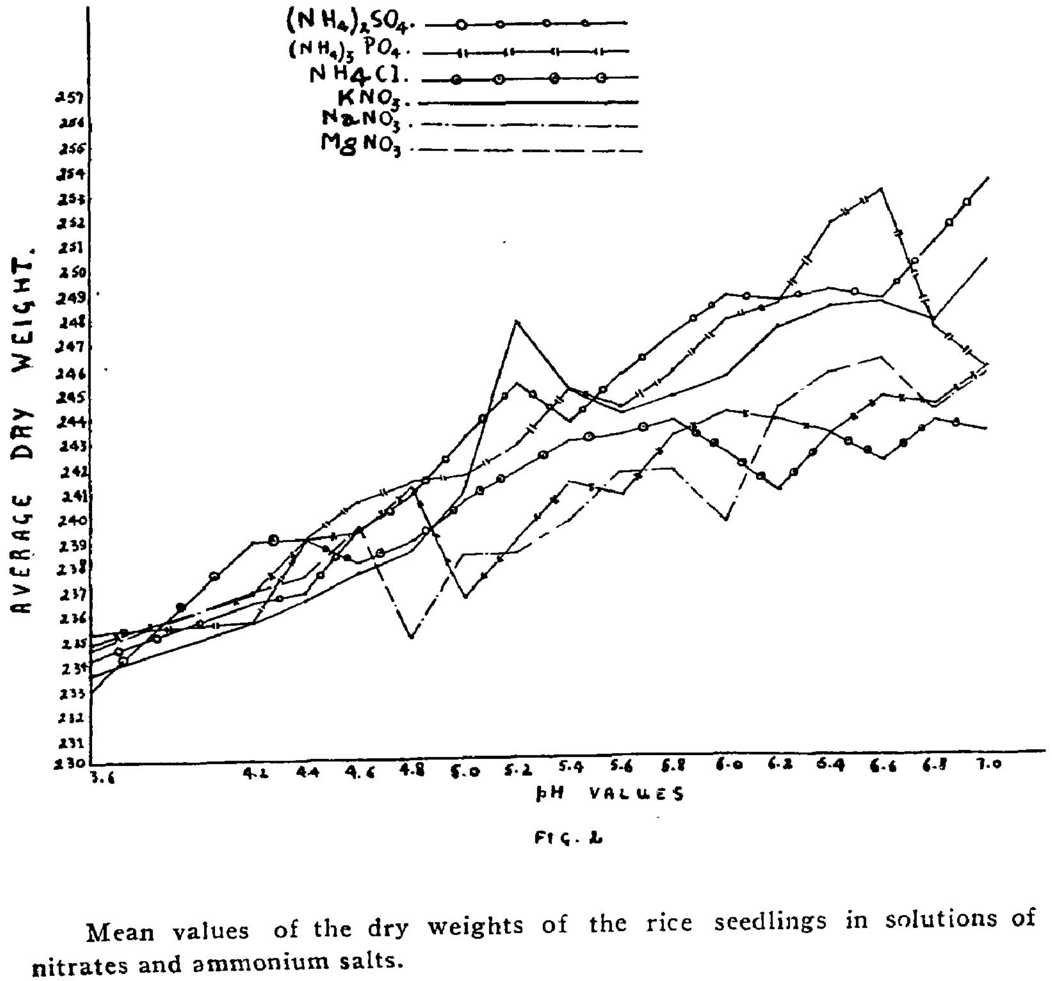


FIG. 2

Mean values of the dry weights of the rice seedlings in solutions of nitrates and ammonium salts.

## TABLE III.

**Mean values of the dry weights of the rice seedlings in solutions of nitrate and ammonium salts.**

| pH | $KNO_3$ | $NaNO_3$ | $Mg(NO_3)_2$ | $(NH_4)_2SO_4$ | $(NH_4)_3PO_4$ | $NH_4Cl$ |
|---|---|---|---|---|---|---|
| 3·6 | 233·6 | 234·6 | 234·3 | 234·2 | 235·3 | 233·0 |
| 4·2 | 235·6 | 236·9 | 236·5 | 236·4 | 235·6 | 238·9 |
| 4·4 | 236·5 | 237·5 | 239·8 | 236·8 | 239·0 | 239·0 |
| 4·6 | 237·6 | 239·5 | 239·3 | 239·4 | 240·5 | 238·0 |
| 4·8 | 238·5 | 235·0 | 241·1 | 240·8 | 241·3 | 238·9 |
| 5·0 | 240·9 | 238·3 | 236 6 | 243 1 | 241·6 | 240·6 |
| 5·2 | 247·8 | 238·4 | 238·9 | 245·3 | 242·8 | 241·7 |
| 5·4 | 245·1 | 239·7 | 241·3 | 243·8 | 245·1 | 243·0 |
| 5·6 | 244·1 | 241·7 | 240·8 | 245 7 | 244·3 | 243·2 |
| 5·8 | 244·8 | 241·8 | 243·2 | 247·4 | 245·8 | 243 8 |
| 6·0 | 245·6 | 239·7 | 244·1 | 248·8 | 247·9 | 242·5 |
| 6·2 | 247·6 | 244·3 | 243 8 | 248·7 | 248·6 | 240·9 |
| 6·4 | 248·4 | 245·7 | 243·2 | 249·1 | 251·8 | 243·2 |
| 6·6 | 248·6 | 246·3 | 244·7 | 248·7 | 253·1 | 242·1 |
| 6·8 | 247 8 | 244·2 | 244·4 | 251·0 | 247·6 | 243·7 |
| 7·0 | 250·2 | 245·7 | 245·9 | 253·5 | 245·9 | 243·3 |

These results of the dry weights of the seedlings are statistically examined according to the method described, in order to determine the salt solution in which highest growth has occurred taking all the solutions of different pH values considered together. The difference between the mean yields in various treatments (*i.e.*, salt solutions) are given in Table IV in which any two treatments may be compared and their relative superiority determined. It will be seen that ammonium sulphate is superior to all other treatments. It is better than ammonium phosphate but the differences between the two are not significant. Sodium and magnesium nitrates and ammonium chloride have proved to be much inferior treatments. Thus the results conclusively confirm the superiority of ammonium

sulphate over potassium nitrate for the growth of rice seedlings in the early stages of growth.

## TABLE IV

**Table of difference between the mean yields.**

| | $KNO_3$ | $NaNO_3$ | $Mg(NO_3)_2$ | $(NH_4)_2SO_4$ | $(NH_4)_3SO_4$ | $NH_4Cl_2$ |
|---|---|---|---|---|---|---|
| $KNO_3$ | — | —23·55 | —22·05 | +14·65 | + 8·50 | —20·85 |
| $NANO_3$ | +23·55 | — | + 1·50 | +38·20 | +31·70 | + 2·70 |
| $Mg(NO_3)_2$ | + 22·50 | — 1·50 | — | +36·70 | +30·20 | + 1·20 |
| $(NH_4)_2SO_4$ | —14·65 | —38·20 | —36·70 | — | — 6·50 | —35·50 |
| $(NH_4)_3PO_4$ | — 8·50 | —31·70 | —30·26 | +6·50 | — | —29·00 |
| $NH_4Cl$ | +20·85 | — 2·70 | — 1·20 | +35·50 | +29·00 | — |

Double lines indicate significance at 1% level.
Single lines indicate significance at 5% level.

It was also undertaken to use a two-salt solution containing three or four different ions in different combinations to study the effect of the different ions when used singly or in presence of other ions. It would also help in determining the effect of the nitrate ions in presence of ammonium salts and *vice versa*, on the growth of the plants. It is not attempted to use all the combinations possible as the number of experiments becomes too large to manage but the following combinations have been used. Ammonium phosphate is combined separately with nitrates of sodium and magnesium. Ammonium sulphate is combined with calcium or sodium nitrate and ammonium chloride is used in combination with calcium or magnesium nitrate. In one series of experiments calcium and magnesium salts are combined to study their effect on the plant while in another case two sulphate salts are combined for the same reason. Side by side, it was found necessary to start a series of experiments with the culture solutions containing all the essential ions.

The results of the dry weights of the rice seedlings grown in different solutions containing mixtures of two different salts and in normal culture solutions are given in Table V.

## TABLE V

**Mean values of the dry weights of the Rice Seedlings in Culture of two salt solutions.**

| pH | Culture | $(NH_4)_3PO_4$ $NaNO_3$ | $(NH_4)_3PO_4$ + $Mg(NO_3)_2$ | $(NH_4)_3PO_4$ $NH_4Cl$ | $NH_4Cl$ $MaNO_3$ | $NH_4Cl$ - $Mg(NO_3)_2$ | $(NH_4)_2SO_4$ — $Ca(NO_3)_2$ | $(NH_4)_2SO_4$ + $MgSO_4$ | $MgSO_4$ + $Ca(NO_3)_2$ |
|---|---|---|---|---|---|---|---|---|---|
| 3·6 | 234·1 | 235·7 | 236·3 | 235·4 | 234·6 | 235·5 | 233.4 | 233·1 | 233·2 |
| 4·2 | 239·3 | 238·0 | 240·0 | 238·7 | 239·5 | 239·0 | 235·1 | 235·4 | 236·4 |
| 4·4 | 241·1 | 236·0 | 240·5 | 239·9 | 239·7 | 239·1 | 236·1 | 235·5 | 234·9 |
| 4·6 | 242·8 | 238·0 | 240·6 | 240·8 | 240·6 | 239·0 | 236·7 | 231·7 | 237·2 |
| 4 8 | 242·9 | 238·0 | 239·1 | 239·4 | 239·4 | 241·0 | 236·7 | 237·6 | 235·6 |
| 5·0 | 244·3 | 236·8 | 240·4 | 239·2 | 240·4 | 239·0 | 230·0 | 237·9 | 238·0 |
| 5·2 | 245·6 | 239·1 | 239·1 | 242·3 | 241·3 | 240·8 | 238·6 | 236·7 | 239·2 |
| 5·4 | 247·6 | 242·5 | 240·4 | 242·7 | 243·1 | 239·3 | 238·7 | 237.4 | 238·5 |
| 5·6 | 248·7 | 243·8 | 242.7 | 243·7 | 243·7 | 240·9 | 239·7 | 238·1 | 239·1 |
| 5·8 | 250·4 | 244·6 | 243·7 | 245·3 | 244·5 | 241·1 | 240·0 | 240·2 | 240·1 |
| 6·0 | 252·7 | 244·6 | 245·8 | 246·3 | 245·2 | 242·6 | 240·1 | 233·9 | 240·1 |
| 6·2 | 253·5 | 245·7 | 246·9 | 247·6 | 245·9 | 244·0 | 241·9 | 240·3 | 240·5 |
| 6·4 | 254·8 | 245·9 | 247·6 | 248·6 | 246·6 | 242·5 | 243·6 | 238·3 | 241·8 |
| 6·6 | 255·7 | 247·8 | 248·9 | 246·7 | 244·4 | 242·8 | 245·4 | 241.9 | 242·1 |
| 6·8 | 256·2 | 244·9 | 247·6 | 246·2 | 243·2 | 239·0 | 245·3 | 238·3 | 243·5 |
| 7·0 | 257·1 | 246·1 | 245·4 | 246·8 | 244·0 | 239·2 | 245·9 | 240·3 | 244·9 |

In the culture solution the dry weights of the seedlings increase steadily as the pH value rises from 4·2 to 7·0 thus agreeing with the results discussed above. Growth of the seedling is retarded in acidic media. The same remarks can be applied to the results of the different mixtures containing ammonium phosphate. In case of ammonium phosphate solution, the best growth is made in solutions of pH 6·2—6·8 (Table V). In the case of ammonium chloride solution with sodium nitrate or magnesium nitrate the pH from 5·6 to 6·6 appears to be the most favourable for growth (Table V). In case of mixture of ammonium sulphate and calcium nitrate the acidic media from pH 3·6 to 5·0 are definitely detrimental to the growth of the seedlings and the best growth is made in the solution of pH 6·6 to 7·0. It is difficult to say the range of pH favourable to growth in case of the mixture of ammonium sulphate and magnesium sulphate as very little increase in dry weights are noticed in all cases. In case of the mixture of calcium nitrate and magnesium sulphate, highest dry weights are obtained near the pH 6·8 to 7·0. In the case of the mixtures of these two salts highly acidic media are injurious to the growth of the rice seedlings. As the results stand in Table V, culture solution appears to be the best solution for the growth of the rice seedlings. The mixtures of the ammonium phosphate with the three different salts are the next best, but the growth of the rice seedlings is not as vigorous as in the case of pure ammonium phosphate solution. The presence of nitrates of sodium and magnesium and ammonium chloride shows a depressing effect (Table V). The mixture of ammonium chloride with sodium nitrate was found better than the mixture of ammonium chloride with magnesium nitrate. In the latter case there is very little growth made by the seedlings. The mixture of ammonium sulphate with calcium nitrate is found less beneficial to the growth of the rice seedlings than ammonium sulphate alone, while the mixture of ammonium sulphate with magnesium sulphate was found definitely bad. The presence of magnesium is found harmful to the growth of the rice seedlings except in the presence of ammonium phosphate.

The statistical examination of the results has been carried out as before and the results of the differences in the mean values of the yield are presented in Table VI. It will be seen that culture is superior to all treatments at 1% level of significance. Mixtures of ammonium phosphate with different salts are the next best of which the mixture of ammonium phosphate and ammonium chloride appears better than the mixture of ammonium phosphate with two nitrates, though the differences between them are not significant. The mixtures of ammonium sulphate with magnesium sulphate and with calcium nitrate have proved to be the most inferior. The same remarks apply more or less to the rest of the treatments.

## TABLE VI.

**Table of differences between the mean yields.**

| | Culture | $(NH_4)_3PO_4$ + $NNO_3$ | $(NH_4)_3PO_4$ + $Mg(NO_3)_2$ | $(NH_4)_3PO_4$ + $NH_4Cl$ | $NH_4CL$ - $NaNO_3$ | $NH_4Cl$ $Mg(NO_3)_2$ | $(NH_4)_2SO_4$ + $Ca(NO_3)_2$ | $(N\ H)_2SO_4$ + $MgSO_4$ | $MgSO_4$ $Ca(NO_3)_2$ |
|---|---|---|---|---|---|---|---|---|---|
| Culture .. .. .. | — | —57·50 | —51·65 | — 48·15 | — 56·65 | — 76·35 | — 88·50 | —103·25 | — 89·05 |
| $(NH_4)_3PO_4 + NaNO_3$ .. | + 57·50 | — | + 5·86 | + 9·35 | + 0·85 | — 18·75 | — 31·00 | — 45·75 | — 31·55 |
| $(NH_4)_3PO_4 + Mg(NO_3)_2$ | + 51·65 | — 5·35 | — | + 3·50 | — 5·00 | — 24·60 | — 36·85 | — 51.60 | — 37·40 |
| $(NH_4)_3PO_4 + NH_4Cl$ .. | + 48·15 | — 9·35 | — 3·50 | — | — 8·50 | — 28·10 | — 40·35 | — 55·10 | — 40.90 |
| $NH_4Cl + NaNO_3$ .. | + 56·65 | — 0·85 | + 5·00 | + 8·50 | — | + 19·60 | — 31·85 | — 46·60 | — 32.40 |
| $NH_4Cl + Mg(NO_3)_2$ .. | + 76·25 | +18·75 | +24·60 | + 28·10 | + 19·00 | — | — 12·25 | — 27·00 | — 12·80 |
| $(NH_4)_2SO_4 + Ca(NO_3)_2$ | + 88·50 | +31·00 | +36·85 | + 40·90 | + 31·85 | + 12·25 | — | — 14·75 | — 0·55 |
| $(NH_4)_2SO_4 + MgSO_4$ .. | +103·25 | +45·75 | +51·60 | + 55·10 | + 46·60 | + 27·00 | + 14·75 | — | + 14·20 |
| $MgSO_4 + Ca(NO_3)_2$ .. | + 89·03 | +31.55 | +37·50 | + 4·35 | + 32·40 | + 12·88 | + 0·55 | — 14·20 | — |

Double lines indicate superiority at 1% level of significance.
Single line indicates superiority at 5% level of significance.

## Summary

In their studies on the intake of nitrogen Dastur and Malkani (1933) have shown that rice seedlings absorb more of ammoniacal nitrogen than the nitrate nitrogen from their respective salts. They have also determined the order of absorption of the ammonium and nitrate ions from their respective ammonium salts and nitrates and they have shown that the ammonium salts stood in the order sulphate, phosphate, nitrate and chloride as far as the absorption of ammonium ion was concerned.

Similarly the nitrates stood in the order ammonium, potassium, magnesium, calcium and sodium.

In the above investigation the effect on the growth of the rice seedlings of the absorption of these ammonium and nitrate ions from different salts is not determined. It is necessary to determine if the greater absorption of the ammonium ion is accompanied by greater growth of the seedlings as compared with the growth of the seedlings kept in solutions of nitrates.

The effect of the hydrogen ion concentration of the salt solution on the growth of plants is well-known and it is therefore necessary to study the growth of rice seedlings in salt solutions of different pH values.

The pH value of each salt solution has great effect on the growth of the rice seedlings. The results show that in all cases the greatest growth occurred in the salt solutions whose pH ranged from about 6·0 to 7·0. Very little or no increase in dry weight was noticed in the salt solutions with low pH values indicating that acidity lower than 6·0 pH was detrimental to the growth of the seedlings.

The results of these experiments were statistically interpreted by using Fisher's method of analysis of variance and as a result of that the following facts emerged.

Culture with Ferric Phosphate was superior to culture with $FeSO_4$. Similarly culture with Ferric phosphate was superior to culture without iron. No difference was found between the culture with $FeSO_4$ and culture without iron. Culture with potassium nitrate as a source of nitrogen was found superior to culture with ammonium sulphate.

Amongst the single salt solutions ammonium sulphate and ammonium phosphate are found superior to potassium nitrate as the dry weights of the seedlings are higher in the former than in the latter. In the other nitrates and ammonium salt solutions the growth of the seedlings is poor.

In the two salt solutions those combinations which contain ammonium phosphate are found to be superior to other combinations.

The ordinary culture solution is found to be the best of all the solutions used.

Thus for the growth of the rice seedlings ammonium sulphate and ammonium phosphate are found to be better than potassium nitrate and the most favourable pH for the growth of the rice seedlings lies between 6·0 and 7·0, *i.e.*, towards the neutral point.

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* Original not seen.

# CONTRIBUTION TO THE KNOWLEDGE OF FLORA AND VEGETATION IN THE CENTRAL HIMALAYAS

BY

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When *A. Heim* and *A. Gansser* in 1936 went on a geological expedition to the central Himalayas they also collected plants. The result of the trip, some 200 species, was given to the Botanical Museum of the University of Zürich, where the plants will be determined. They also made ample notes concerning Flora and Vegetation, chiefly in the alpine region, which allow us to form a good idea of the distribution of the Flora there. In the following we will try to sketch its relations to the great eurasiatic vegetation units.

## The subalpine Forest Belt (Larch-Pinus Cembra Belt)

In the valleys of the northern Kumaon, in the frontier region towards N. W. Nepal and Tibet, the subalpine forest consists mainly of *Betula utilis* (see plate IX); occasionally, Conifers *Pinus excelsa* and *Abies spectabilis* (=*A. Webbiana*) are so frequently to be found that they predominate in the aspect of the forest. In the Kali valley, between Tinkar and Garbyang, a forest of birch and white spruce with solitary pines is mentioned, below Changu an "aromatic pine forest", again above Garbyang rear Kalapani (3800 m) a pine forest, and the same between Gunji and Garbyang "along the road" and near Gunji (3175 m). Near Sepu (3490 m), a birch wood intermixed with some firs was seen on the shady side, near Rilkot "in Tola" "some fir wood", along the Kuari pass at 3500 m "firs with Rhododendron," and there also, between 3550 and 3650 m altitude a birch forest with "oak and big Rhododendron." On gravel terraces and cones of rubbish, Conifers predominate very frequently (see Pl. X). *Betula utilis* reaches enormous size. The Holy Birch near Tijang in the Valley of Lissar, at an altitude of 3300 m, has been found by Heim to have

a diameter of 25 m in the crown, and its two main trunks measure 1.5 and 1.2m (see Pl. XI). Near the limit of the forest the trees are smaller and crooked, as in *Betula tortuosa* of the Alps.

The undergrowth of the subalpine forest consists of shrubs of Rhododendron species such as *Rh. Anthopogon, Rh. campanulatum, Rh. lepidotum*, then *Lonicera*—, *Ribes*—, *Cotoneaster*—, *Rosa species*, and between them some few *Podophyltum, Allium, Cortusa Matthioli, Primula nivalis* and others.

There is no fully matured soil, as the steep slopes do not permit it. Considerable layers of raw humus are often lying on the mineral soil which is so little weathered that the humus can easily be carried away. The soil of pine woods on gravel terraces or cones too has often A—C profiles, *i.e.*, the humus lies directly on the not or only very little disintegrated mineralic ground.

The subalpine zone dominates the region between 3100 and 3900 m of altitude (near Kuti and in the Soringonga valley along the Dutuk Dhura-pass up to 4000 m), but it is well developed on the north-exposed slopes only. On the south-exposed sides of the larger valleys, the forest is scanty or even missing completely, either destroyed by men (fire places frequent) to gain pasture ground, especially near villages and caravan tracks, or due to climatic conditions, as dryness does not allow the forest to develop. Its place is taken by low shrubs of *Juniperus communis, J. Wallichiana, Cotoneaster*—, *Rosa*—, *Salix*—, and other species with a more xeric character than the society of Betula-Rhododendron. Nevertheless, mixed with these shrubs are some high herbs of subalpine character, such as *Rheum, Anemone, Geranium, Podophyltum, Epilobium latifolium, Sweertia petiolata*. In more humid places were found luxuriant meadows of herbaceous perennials; when going up from Ralam to the Dutuk Dhura-pass, Heim noticed luxuriant perennials of manured lair flora, and plains covered with fern, on the Ralam-pass high grown meadows with *Pedicularis*—, *Gentiana*—, *Geranium*— and *Orchis* species, in the dryer valley of Kuti places with *Primula*—, *Myosotis*—, *Ranunculus*—, *Geranium*—, *Corydalis*—, *Delphinium*—, *Aster* and *Anaphalis* species, *Hierochloa laxa, Polygonum affine, Anemone polyanthes, Kaschmirica*, etc. Extensive thickets of *Rosa sericea* and the less spread *R. macrophylla, Prunus* species on road sides and near villages depend on the influence of man; alpine pastures, which are found chiefly on moraine ground and gravel terraces are very rich in flowers (in July); in the valley of Kuti, *Potentilla argyrophylla* with its yellow or red flowers was surprisingly frequent. Already our actual scanty knowledge of the subalpine forest zone of the Himalayas is sufficient to show that we can very well compare it to corresponding regions in Eurasia. Most genera occur in vicarious, partly even in identical species. Such a forest belt, consisting of larch-trees, pines, and birches, forms the upper zone of all mountain forests, from Himalayas over the west—, central— and north-Chinese mountains to the subarctic Siberian plains and

to North-America, and from the South Siberian mountains to the mountains of north and central Europe. The vegetation of the inner Kumaon valleys also shows a great physiognomic resemblance to that of the central Asiatic mountains, Tianshan, Altai, and even to the dry inner alpine valleys. The north-exposed slope is covered with forest of *Pinus* spec., *Betula* resp. *Larix*, with a luxuriant undergrowth of Rhododendron; on the south-exposed side we find here and there isolated woods of these species of trees, surrounded by large bushes of Juniperus. Forests of larch, pine or birch are here limited by the forest-steppe. In the inner alpine chains, the larch—*Pinus Cembra* stage lies about 1500 m lower than in north Kumaon, between 1500 and 2400 m; in eastern Afghanistan between 3000 and 4000 m, in Hindukusch between 3000 and 4000 m, in the eastern Himalayas between 3000 and 4300 m; in east-Tibet between 3200 and 4300 m, reaches in Tsinling-shan up to 3200 m, in Wutai-shan up to 3000 m, and in Wuling-shan up to 2200 m (compare Limpricht, 1922). The richest flora of this belt is found in the old mountain center of East-Tibet, in West-China, and in south-eastern Siberia; it is poor in the north-western plains and in Europe. As in the Alps, this vegetation belt has also its southern limit in the Himalayas but here it is much better represented. Whereas in the Alps, the glacial periods have separated the flora types of the subalpine (and alpine) belt from those of lower zones in such a way that their genetic relations to these lower positions have been destroyed and are only found as relicts in island-like places, in the Himalayas (and still more in the east-asiatic mountains) the stock of species of the subalpine belt is much more genetically connected with that of the lower belts (compare Diels 1901); one has to think only of the genera *Delphinium, Thalictrum, Corydalis, Astragalus, Vaccinium, Rhododendron, Sweertia, Scrophularia, Pedicularis, Scutellaria, Prenanthes, Saussurea,* and others.

If the subalpine forest belt of the Himalayas is much better developed than in the Alps, this is because there was no destruction in the glacial period (Heim says that the glaciers did not come down to an altitude lower than of 2000 m), and it is much nearer to the floristically rich regions of the East. In both mountains, a large part of the flora of this belt has an autochthonous character.

In this subalpine belt, the cultivation by man is found as high as 3660 m in Ralam, 3490 m in Sepu, 3425 m in Milam, 3750 m in Kuti. In these fields are cultivated 6-rowed barley (even at 4300 m), potatoes, buckwheat, spinach, parsley, onions, radishes, and turnips. In Kuti there was found an area of about 1 km. sq. with two sorts of barley and two species of buckwheat. Potatoes are sown about the 10th June, and gathered in October. The cultures suffer from late frost and sudden heat. In the high villages, only a few families remain in winter, as for instance 3 out of 80 in Kuti.

## The Pulsatilla—Forest-Steppe—Belt

The subalpine forest has two climatic boundaries, one thermic, which is in Kumaon at the same time the altitude limit for the birch—Rhododendron forest, and for the forest on the whole, and another which is a xeric limit. At this xeric limit there is a zone of clear forest or bush between forest and steppe in which is found an undergrowth of temperate xerophile herbs and shrubs, to a large extent bioclimatically independent of the tree-species. This forest-steppe belt is frequent in the northern part of Eurasia; it encloses in the south the eurosiberian forests of conifers, enters in Europe for reasons of plant history (displacement of Taiga in the glacial period) into the regions of angiosperm forests. The same occurs in northern East-Asia. It is found on the dry slopes of the steppe-mountains in Central-Asia, and occupies the southern slopes of the dry mountain valleys from the Alps to the North-Chinese mountains. For the Pulsatilla-forest-steppe belt are characteristic: *Pinus*—, *Juniperus*—, *Pulsatilla*—, *Astragalus*—, *Berberis*—, *Caragana*—, *Erysimum*—, *Festuca*—, *Galium* (boreale, verum)—, *Goodyera*—, *Koelcria*—, *Onosma*—, *Thesium*—, and other species.

We conclude from Heim's notes and collections that this belt is not well represented in Kumaon. There are mentioned on the south-exposed slopes of the innermost valleys from altitudes below and above those of the subalpine birch forest belt, dry shrubs, for instance in the Satopnath valley above Badrinath at 3700 m *Juniperus Wallichiana*, *J. cf. communis*, *Ephedra Gerardiana*, *Salix* spec., from Gunji on gravel cones up to 3900 m forming thick bushes with *Juniperus cf. communis*, *J. Wallichiana*, *Rosa*—, *Ephedra*—, *Ribes*—, *Cotoneaster* species; at Tinkar down the valley to Garbyang in positions exposed to south with *Juniperus Wallichiana*, *Rosa*—, *Berberis*—, *Cotoneaster* species; near Tola-Milam 3300 m, 2 *Juniperus*—and 2 *Cotoneaster* species, whereof one with tree-like habit grows to 2 m height. *Juniperus Wallichiana* is very frequently noted; it is much used as fire-wood, "the only wood in Kuti"; it is found there up to 4600 m, and is reported not to grow from Uttadura-pass northward. There has been collected near Kuti out of the Juniperus-Wallichiana—society: *Rosa macrophylla*, *R. sericea*, *Stellera Chamaejasme*, *Hierochloa laxa*, *Scutellaria prostrata*, *Erysimum hieraciifolium*, *Myosotis* spec., *Arenaria Kashmirica*; on lime: *Callianthemum pimpinelloides*, *Anemone* spec., *Geranium* spec., *Thymus Serpyllum*; on pastures: *Iris* spec., *Polygonum affine*, *Anemone* spec., *Potentilla argyrophylla*, *Morina Coulteriana*, *Dracocephalum* spec., *Macrotomia Benthami*; near Milam-Rilkot: *Leontopodium Stracheyi*, *Anaphalis* (some species), *Cyananthus linifolius*, *Aster* spec.

The Pulsatilla—forest-steppe—belt contains in the Himalayas only few endemic species; there is for instance *Juniperus Wallichiana*, nearly related to *Juniperus pseudosabina*, moreover *Lonicera*

*glauca,* several species of *Nepeta* and others. The neighbouring eastern regions have also contributed very little to this belt; here must be mentioned the genera *Juniperus (recurva, squammata), Adonis, Berberis, Leontopodium;* much more extensive is the western influence which is represented by the genera *Avena, Bromus, Pulsatilla, Erysimum, Cynanchum, Teucrium, Phlomis, Onosma, Galium, Lactuca,* and others. This poor development of the belt in the central Himalayas is due to the small area in horizontal and vertical direction suited for it. In the south, the valleys are soon too humid, and where they are dry enough, they are too hot (here dominates *Pinus longifolia*). On the Tibetan Highland, however, the altitudes are above what is suitable for trees. From the want of endemics, we conclude a comparatively young age of that belt in the Himalayas: already in the upper Indus valley, in Hindukusch, in Tianschan, the belt is much more complete; but also in the east, in eastern Tibet (up to 4500), in the mountains around the Kukunor, in Nanschan, Alaschan, it must be much more developed concluding from the flora-lists and descriptions of vegetation at hand. Its main-region lies between the eurasian conifer—and steppe zones. With reference to a large part of its species, it can be considered genetically as a xeromorphose out of the tertiary conifer region, beginning already with the upward-movement of the alpides.

## The Alpine Dwarf Shrub—Tundra

*(The Vaccinium uliginosum—Loiseleuria—Belt)*

To conclude from the observations made by Heim and Gansser, the birch—Rhododendron forest on the north-exposed slopes is limited by a horizontal line, without dissolving in solitary trees. Steep rocks and grooves of avalanches are the only interruptions of this line. Above the forest, at about 3900 to 4000 m, begins the region of alpine dwarf shrubs with *Rhododendron Anthopogon, Rh. lepidotum, Rh. campanulatum, Cassiope fastigiata,* and others, with a luxuriant growth of moss and lichens and with alpine herb meadows. The dwarf shrub heath prefers the north-exposed slopes, the meadows the south-exposed valley sides. Closed Rhododendron areas are found up to about 4300 m; *Rhododendron Anthopogon* has been seen at the Satopnath-glacier at an altitude between 4600 and 4700 m. The ground consists of a layer of raw humus on a very little weathered mineralic underground. The meadows are very rich in species. On the Chaga-pass were collected in a pastured meadow: *Aletris nepalensis, Allium cf. auriculatum, Fritillaria Stracheyi, Anemone* spec., *Sedum quadrifidum, S. crenulatum, Potentilla argyrophylla, Viola biflora* in a very hairy form; near Kuti: *Iris cf. kumaonensis, Polygonum affine, Anemone polyanthes, Potentilla argyrophylla, P. ambigua, Geranium* spec., *Primula* div. spec., *Veronica capitata,* div. *Pedicularis* spec., *Anaphalis nubigena;* on the Shialapass: *Lloydia serotina, Orchis spathulata, Isopyrum grandiflorum, Cardamine*

*pratensis var., Potentilla argyrophylla, Geranium* spec., *Primula* spec., *Anaphalis nubigena, Aster flaccidus;* along the Ralam-pass a "paradise of flowers," with: *Juniperus Wallichiana, Meconopsis aculeata, Corydalis Gortschakovii, Potentilla* spec., *Pedicularis rhinanthoides, P. cf. macrantha, Leontopodium leontopodinum;* in the Nampa valley: *Lilium nepalense, Thermopsis barbata, Gentiana pygmaea var. acuminata, Lancea tibetica;* on a marshy bank of a brook in the west of Ralam at 4000 m: *Pedicularis tubiflora;* near Laptal, at 4200 m: *Gentiana humilis* var. *evolutior, G. Moorcroftiana, Pleurogyne carinthiaca, Pl. spathulata, Scutellaria* spec., *Aster* spec.; near Kuti, 4100 m: *Primula involucrata;* in a boggy depression on clay in the Chaga valley at 4200 m: *Veronica Anagallis, V. biloba, Parnassia pusilla;* on moraine ground of the Lebong pass: *Delphinium* spec.; on the Ralam pass: *Fritillaria oxypetala, Orchis spathulata, Corydalis* spec., *Pedicularis* spec.; in the Nampa valley: *Lloydia sorotina, Saxifraga Stolitzkae, Viola biflora, Androsace villosa* var. *Jaquemontiana, Lancea tibetica, Eritrichium spathulatum, Anaphalis nubigena;* on lime rubbish near Kuti: *Anemone polyanthes, Callianthemum pimpinelloides, Trigonella corniculata, Geranium* spec., *Stellera Chamaejasme, Thymus Serpyllum;* on rubbish of lime slate on the Chaga pass: *Lagotis spectabilis, Primula nivalis* var. *macrantha, Corydalis Gortschakovii;* on lime rocks near Kuti: *Juniperus Wallichiana, Isopyrum grandiflorum, Bergenia Stracheyi;* near Kalapani: *Lloydia serotina, Anemone rupicola, A. polyanthes, Saxifraga Stolitzkae, Potentilla bifurca.* On the south-exposed slopes of the inner valleys, with approach to the high plains, more and more species of the steppe are intermixed with the plant genera of the lower alpine belt (see below).

A large part of the species, and most of the genera of this lower alpine belt appear to come from the east, from east Tibet, western China and the adjoining northern East-Asia. There lies the centre of development of the Orophytes of the genus *Tofieldia, Rheum, Meconopsis, Delphinium, Rhododendron, Gentiana, Primula, Androsace, Sweertia, Pedicularis, Aster, Leontopodium, Saussurea,* and others, while the relations to the north-west are much less numerous. Plant societies of the belt dominated by Ericaceae are completely missing in the central- and west-Asiatic mountains (in the Tianshan and Altai they are seen only on the northern mountain side), and are found again only in the caucasus, in the Balkan and in the Alps. The belt of *Vaccinium uliginosum, Loiseleuria* is found in the central Himalayas as a small zone, enlarging fan-like towards the east, over the east-Asiatic mountains to the arctic plains, where it encloses the northern hemisphere in a large zone poor in species, limited in the south by the subarctic forest. Towards the west, the belt enlarges also, but is found only island-like and very poor in the central- and west-Asiatic mountains, becoming again more complete in the caucasus and in the European mountains.

In the Himalayas the belt is autochthonous; that must be concluded from the genetic relations to species of lower regions (Diels 1901), and from the numerous Endemics of high value. Just as in the other areas of its original regions, it is a production of orophyts from the conifer-zone with older parts from the tertiary angiosperm forest regions, beginning with the upward-movement of the alpides. Richness in species and the genetic union of the flora-types with the flora of the lower regions show distinctly that the Eurasiatic mountains, mainly the east-Tibetan-Chinese mountains, and not the arctic circle, are the centre of origin of this flora as has already been mentioned by *Grisebach* 1872.

The influence of man in the lower Alpine region is unimportant, and is only found by pasturage near the caravan paths.

## The Carex—Elyna—Belt

The meadows of the highest vegetation belt expand above the dwarf-shrub heath and the luxuriant meadows of the lower Alpine zone, at an altitude of about 4300m. This belt is found in pioneer turf up to 4900m and in single individuals upto 5500m. The snow limit is found by Heim and Gansser to be in the inner valleys at 5300 to 5500m, near the Tibetan frontier at about 5600m. In this upper Alpine region, there is not only the upper thermic limit for phanerogamic plants, but also the dry-limit, that is the limit beyond which all precipitation is evaporated again, without deposition downwards. On the Himalayan side of the mountain passes, there are still flourishing continuous turf societies, interrupted only by rubbish or rock ; on the Tibetan side, they are limited to flat moulds containing ground-water and to the banks of periodical watercourses. Here, the vegetation is dominated by Gramineae and Cyperaceae. In such places was still found brown-black humus, as for instance at the *Tinkar-Lipu*—pass, 4760m, and in a depression near by, at 5100-5200m, boggy soil with *Braya rosea*, *Draba alpina*, *Ermania himalayensis*, *Lagotis* spec., and plenty of *Ranunculus pygmaeus*, (found here for the first time in the Himalayas), as well as *R. nivalis*, which, up to the present, was considered as chiefly arctic. Below the pass, between 4500 m, there were observed in the turf : *Oxygraphis glacialis*, *Ranunculus pygmaeus*, *Sedum* of the Tribus *himalensia*, *Saxifraga Stolitzkae*, *Potentilla* spec., *Primula nivalis* var. *macrantha*; at Amlang-La, 4700 m, in a meadow above groundwater : *Sedum* spec., *Oxytropis* spec., *Primula tibetica*, *Pedicularis Oederi*, *P. rhinanthoides*, *Microula Benthami*, *Taraxacum dealbatum*, *T. leucanthum*, *Aster* spec. ; near Junglea, spongy meadow with : *Oxytropis proboscidea*, *O. microphylla*, *Gentiana humilis* var. *evolutior*, *Saussurea* spec., *Taraxacum leucanthum*; on the Ralam pass, at 4600 m : *Juncus leucomelas*, *Anemone* spec., *Saxifraga cf. nana*, *S. sibirica*, *S. pallida*, *Gentiana Wardii*, *G. tubiiflora*, *Leontopodium* spec., *Anaphalis nubigena*; near the Satopnath glacier in turf at 4600 m : *Gentiana nana* and *G. cf. depressa* ("all the rest dry," 7 X. 1936) ;

Dolma-La at 5100 m on a level meadow; *Parrya exscapa*, *Veronica* spec., From the Uttadura-pass Heim writes that there was only " hard green, stuffed-plants, mosses, dwarf enzian" : 400 goats and sheep out of 800 were killed by bad weather lasting five days and by want of food. On moraine and rubbish were collected at the Lipu Lek—pass, between 4700 and 5200m : *Polytrichum*—, *Dicranum*—, *Hedwigia*—, *Tortella*—species, *Ranunculus pygmaeus*, *Draba* spec., *Sedum* of the Tribus *himalensia*, *Chrysosplenium carnosum*, *Saxifraga setosa*, *Primula minutissima* var. *spathulata*; near Kuti on rock and rocky rubbish at 4800m : *Saxifraga sibirica*. *Gentiana capitata*, *Androsace villosa* var. *villosissima*, *Primula nivalis* var. *macrophylla*; near the Raksaslake, at 4600m : *Arenaria musciformis*, *Dracocephalum heterophyllum*, *Marrubium* spec., *Allardia tomentosa*; at Dolma-La, south side, 5500m, between granite blocks: *Urtica cf. hyperborea*, *Draba altaica*, *Potentilla* spec., *Astragalus Heydei*, *Astr. confertus*, *Veronica cf. bilboa*, *Leontopodium nanum*; at Mangshang-La, between 4700 and 4850m, on dry rubbish : *Sedum fastigiatum*. *Oxytropis* spec., *Eritrichium strictum*, *Pedicularis globifera*, *Aster flaccidus*, *Leontopodium leontopodinum*, *Senecio arnicoides*, *Allardia tomentosa*, *Saussurea scrocephala*; at Amlang-La, 4700m on rubbish : *Hedinia tibetica*, *Torularia humilis*, *Pedicularis* spec., at the Ralam pass on rubbish : *Rheum* spec., *Saxifraga flagellaris*, *Allardia glabra*, *Anaphalis nubigena*; there also at 4600 m : *Wahlenbergia gracilis*; at the Kiangur pass, between 4600 and 4900m : *Delphinium* spec., *Saxifraga flagellaris*, *Gentiana aquatica*, *Pleurogyne brachyanthera*, *Microula Benthami*, *Lamium rhomboideum*; in the *Chidamu-gorge* at 5000m : *Gentiana frigida*. var. *nubigena*, *Leontopodium monocephalum*; in the eastern Lap valley on flysch back between 5000 and 5200 m : *Gentiana frigida* var. *nubigena*, *Senecio cf. retusus*; near Balchadura between 5200 and 5300m : *Gentiana nana*, *G. frigida* var. *nubigena*, *Nepeta longibracteata*, *Pedicularis globifera*; at the Balchadura—pass at 5400m on rubbish : *Potentilla fruticosa* var. *pumila*; and on moraine at 4900-5000m : *Thylacospermum rupifragum* in cushions of up to 2·5m diameter ; at 5450m still *Senecio arnicoides*; along the Chirdum pass, 5300m : *Saxifraga viscidula*; at the Chalda pass, 5300m, *Delphinium vestitum*; on the Lipulek pass on rocks between 4800 and 5300m : *Stereocaulon*—, *Evernia*—, *Cladonia* species, *Draba setosa*, *Saxifraga imbricata*, *S. Stoliczkae*, *Chrysosplenium carnosum*; on a rocky ridge near Kuti, 4800m, *Corydalis cachemiriana*.

The Carex—Elyna belt possesses in the innermost Himalayan chain rich *fittings* of species, genetically bound to the flora of lower regions ; nevertheless it contains a very strong falling gradient of flora form the Tibetan-Chinese mountains between Yünnan and Kukunor ; in the frontier region near Tibet, their number falls down to a few hundred species. Genera as *Eutrema*, *Ptilotrichum*, *Parrya* and others indicate central Asiatic influence. Old highly valued endemics are frequent. Their number increases by itself with the altitude, owing to increasing isolation and specialisation.

They can follow much less all displacements, due to change of climate, than species in the lower belts. These Orophytes are remarkable especially on account of their xeric development. High mountains and desert-climate at the same time produce forms like that of *Saussurea gossypiphora, S. tridactyla,* with stem and foliage covered with a mantle of hair like wad. Many of these characteristic species are widely and equally spread in Tibet and the adjoining Himalayan valleys, *e. g. Arenaria musciformis, Thylacospermum rupifragum, Microula Benthami, Lancea tibetica, Nepeta longibracteata, Aster flaccidus,* and others.

The centre of development of the Carex—Elyna belt lies in the central-Asiatic mountains; the north-American, as well as the European mountains are much poorer. From Central-Asia it has reached, chiefly over the east-Asiatic mountains, the arctic circle, and from there it has sent again during the glacial periods many species to more southern mountains.

## The Stipa-Steppe—Belt

At the altitude of the subalpine forest already, in fragments of forest-steppe, on south-exposed dry rocks, and then high up in the upper Alpine region, Heim and Gansser have collected and noted some solitary Stipa-steppe types. Very frequent is *Ephedra Gerardiana* var. *Wallichii; Potentilla fruticosa* climbs as *P. biflora* near Kuti up to 5000 m; *Trigonella corniculata, Carex supina* seem to be rather frequent. Near the Kiangur, they found *Lamium rhomboideum*, near Kuti *Arenaria kashmirica* and *Morina Coulteriana.* Unfortunately, Gramineae and Cyperaceae, which are so important for the recognition of grass societies, have not been collected. All species of this kind, especially the representatives of half-deserts and deserts, not seldom on the Tibetan plain, come from lower regions but they can withstand, owing to their xeric structure, the extreme climate of the higher belts. The Stipa-steppe is found in eastern Tibet and in China, in the north of Tsinling-Shan, to quite a remarkable extent, but the major part of the species in Kumaon and the adjoining Tibet come from north and west (e.g. species of *Elymus, Carex, Stipa, Caragana, Scutellaria, Nepeta, Artemisia,* and others). The number of species, and the number of endemics of these belts is relatively small. It increases towards west and north-west, just the reverse of the Carex—Elyna and the *Vaccinium uliginosum*—Loiseleuria belts. The genetic relations also point to the west; these three xeric belts must be considered therefore as a recent contribution to the central Himalayas. There reaching the upper Alpine regions, and the absence of all forest belts, even of the lower Alpine belts, is a phenomenon repeated only in the Bolivian Andes (with ecological equivalents).

Collections of plants have been made only in the Alpine regions, over 4000 m, but ample notes of Heim give some indications about the vegetation in lower areas. There seems to be no spruce belt, as in middle and eastern Europe and in parts of northern Asia, between subalpine, subarctic and angiosperm forests; this acidiphile vegetation, demanding a moderately cool climate with ample precipitation, does not find these conditions in the central Himalayas. The beech belt is represented by forests, rich in herbs of *Abies Webbiana*, resp., *A. Pindrow*, *Cupressus torulosa*, *Taxus baccata*, *Ilex* spec., *Quercus cf. semicarpifolia*, *Hedera Helix*; in the undergrowth near Shankula: *Polygonatum verticillatum*, *Circaea lutetiana*, *Fragaria vesca*, *Oxalis Acetosella*, *Rubus*, *Impatiens*, *Ferns*, *Rhododendron*. The best development is attained on north-exposed slopes, between 2500 and 3000 m. Below we find, just as in Europe, and eastern Asia, a region very rich in woody plants, the belt of Quercus—Tilia—Acer, with deciduous leafy oaks, *Aesculus indica*, *Juglans regia*, 5 *Acer* species *Picea Morinda*, in damp places between 2000 and 2500 m, and below, the evergreen subtropical angiosperm forest, interrupted on long distances by the more drought-resisting *Pinus longifolia* vegetation.

There remains to be done still much hard and patient work in floristics, systematics and phytocenology (especially concerning the small geographic races), before we can succeed in writing a description of this beautiful world of plants in those stupendous mountains.

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Photo A. Heim

Kali River above Garbyang; view towards N. E. 3,050 m. Probably *Pinus excelsa*.

Photo A. Heim

The sacred birch near Tijang, Lissar valley 3,300 m.

Photo A. Heim

Upper forest—limit near Kuti, 3,800 m. with *Betula utilis*.

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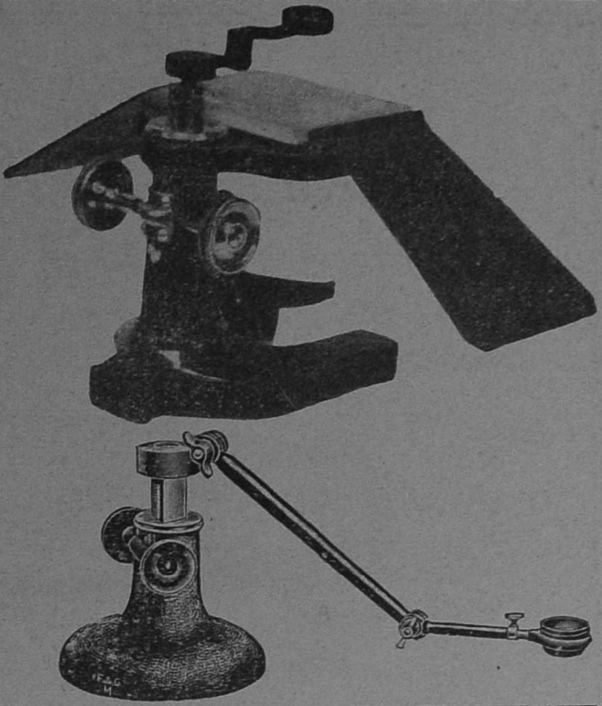

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